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INSPECTION MAINTENANCE OF LIGHT DUTY VEHICLES IN THE DENVER AIR QUALITY CONTROL REGION

TRW, Incorporated

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This report summarizes information on inspection/maintenance programs for the reduction and control of automobile emissions. It deals specifically with inspection/maintenance of light duty vehicles in the Denver Air Quality Control Region. The focus is on the benefits, costs, and other factors connected with the various inspection/maintenance options. The information is intended for use by advisory committees, the Colorado Air Pollution Control Commission, and legislators to aid in the development of enabling legislation in the 1975 Colorado legislative session.

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EXECUTIVE
SUMMARY

INSPECTION MAINTENANCE OF LIGHT DUTY VEHICLES

in the

Denver Air Quality

Control Region

NOVEMBER 1974

TRW / TRANSPORTATION & ENVIRONMENTAL OPERATIONS

INTRODUCTION

Compliance with air quality standards is the goal of the State of Colorado's Transportation Control Plan. An important area of concern is the automobile and its contribution to air pollution. There have been a number of proposals for reducing automobile pollutants, one of which involves a program of inspection/maintenance. Various tests, surveys, and studies show that inspection/maintenance can be a major factor in reducing automotive exhaust emissions.

The attempt here is to bring together the pertinent information that is available on inspection/maintenance for the Denver Air Quality Control Region, and to summarize the findings. In order to initiate an inspection/maintenance program in time to help achieve the goals of the Transportation Control Plan, legislative action is required this session. This report is intended to assist in consideration of such legislation.

A separate volume of this report contains backup data to support the information and conclusions presented herein.

HERE'S WHAT WE FOUND:

- Inspection/maintenance is a proven means of achieving emission reductions now and of preserving the gains resulting from new car improvements or retrofit programs.
- State run inspection lanes using idle test mode with maintenance in the private sector is the most cost effective option. Facilities with room to add loaded mode tests at later date are recommended.
- State operated lanes incur construction and real estate costs not required in a privately operated program, but lower labor costs and higher throughput rates tip the scales in favor of a state operated system.
- An annual inspection program appears most attractive in terms of costs and potential benefits. Survey results indicate, however, that a majority of the Colorado motoring public would favor a semi-annual program.
- Public inconvenience is greatest in a state lane approach in terms of travel distance, waiting time and number of trips required. A combined safety/emission lane, privately operated to allow tests and maintenance at the same location would minimize the inconvenience to the public.
- A maximum dollar limit in the extent of required repairs should be established. A value in the range of $100 – $150 or 20% of retail blue book price appears reasonable.
- Pre-1968 vehicles should be considered for exemption from the inspection program because they will generate only a small percentage of the emissions from the vehicle population and will be relatively expensive to maintain.

TABLE 1

SUMMARY OF TRANSPORTATION CONTROL PLANS

AQCR	I/M	RETROFIT	TRANSIT IMPROVEMENT CARPOOLS	AUTO RESTRICTIONS
BALTIMORE	YES	YES	YES	YES
BOSTON	YES	YES	YES	YES
CHICAGO	YES	YES	YES	NO
CINCINNATI	YES	NO	NO	NO
DALLAS	NO	NO	YES	NO
DENVER	YES	YES	YES	YES
FAIRBANKS	YES	YES	NO	YES
FRESNO	YES	YES	YES	YES
HOUSTON	YES	YES	YES	YES
INDIANAPOLIS	YES	NO	NO	NO
LOS ANGELES	YES	YES	YES	YES
MINNEAPOLIS	NO	YES	YES	NO
NEW YORK CITY	YES	YES	YES	YES
PHOENIX	YES	YES	YES	YES
PITTSBURGH	YES	YES	YES	YES
PHILADELPHIA	YES	YES	YES	YES
PORTLAND, ORE	YES	YES	YES	YES
ROCHESTER, N.Y.	YES	NO	NO	NO
SACRAMENTO	YES	YES	YES	YES
SALT LAKE CITY	YES	YES	YES	YES
SAN ANTONIO	YES	NO	YES	NO
SAN DIEGO	YES	YES	YES	YES
SAN FRANCISCO	YES	YES	YES	YES
SEATTLE	YES	YES	YES	YES
SPOKANE	YES	YES	YES	YES
SPRINGFIELD, MASS	YES	NO	NO	YES
WASHINGTON, D.C.	YES	YES	YES	YES

INSPECTION/MAINTENANCE AS A MEANS FOR CONTROLLING EXHAUST EMISSIONS

Twenty-six Air Quality Control Regions besides Denver have submitted Transportation Control Plans to the Environmental Protection Agency. Inspection/maintenance is included in more of these plans than is any other method of pollution reduction and control. This is shown in Table 1.

While inspection/maintenance has become popular as a candidate strategy for controlling exhaust emissions, there has been a considerable time lag in most areas in translating the strategy into a working program. Table 2 summarizes the active programs outside of the Denver region.

- **Inspection/Maintenance is Effective for New Cars, Old Cars, and Cars with Retrofit Emission Control Devices**

What about inspection/maintenance on new cars? Great strides have been made in pollution control for automobiles. By 1977, a new car will contribute less than 10% of the pollutants generated by a 1967 model of comparable size. Although the engines of both vehicles are nearly identical, various accessories and modifications are used to control or reduce pollutants from the new cars before they escape from the exhaust.

The new pollution-control components – such as positive crankcase ventilation valves, exhaust gas recirculation systems, and catalytic converters – are themsleves subject to deterioration. They must be added to the list of other engine components when considering the problem of wear and malfunction. In fact, the malfunction of these new devices can increase pollutants above the levels of vehicles not equipped with these type devices. An inspection/maintenance program is important to assure that the new, low-emission vehicles perform effectively after they leave the showroom.

What about retrofit programs? Eventually, the newer low-emission vehicles will replace the older vehicles. Recognizing that this attrition process is relatively slow, the Colorado Transportation Control Plan includes a retrofit program for older cars. This program calls for an add-on-device to reduce exhaust emissions until these cars are phased out of service. Periodic inspection/maintenance is necesary for these retrofit systems if they are to perform effectively during the service life of the vehicle. Table 3 shows inspection/maintenance effectiveness for the various kinds of vehicles relative to their status as pollution contributors.

TABLE 2

SUMMARY OF ACTIVE INSPECTION/MAINTENANCE PROGRAMS

Area	Program	Remarks
New Jersey	Combined safety/emission inspection on state lanes—idle mode-mandatory repair and retest until passed.	Currently rejecting 10% of vehicles tested. Standards to become more stringent within a year
Chicago	City lanes performing two stage idle test—mandatory elements of program not firm.	
New York City	Fleet operators of taxi cabs required to test vehicle annually in loaded mode test.	
	Trucks and buses being tested in experimental program to extend inspection/maintenance to heavy-duty vehicles.	Only current program involving heavy-duty vehicles
Washington, DC	District operated lanes for loaded testing. Maintenance requirements not yet established.	
Portland, Ore.	State-run lanes under development for idle mode testing.	Program becomes mandatory July 1975
Arizona	State lanes for loaded mode testing recently became operational in Phoenix.	
Los Angeles County	Mobile check stations perform combined safety, idle emissions test. Failed vehicles must undergo necessary maintenance at state certified smog control stations.	
	One major oil company offers free idle emissions tests at several of its franchised outlets in county. Maintenance voluntary.	

TABLE 3

**INSPECTION MAINTENANCE EFFECTIVENESS*
(DENVER AIR QUALITY CONTROL REGION)**

• For the total automobile population	Inspection/maintenance can reduce :	
	Hydrocarbons	10%–15%
	Carbon monoxide	5%–12%
	Oxides of nitrogen	1%– 2%
– For pre-1968 automobiles	Inspection/maintenance can reduce	
	Hydrocarbons	3%–12%
	Carbon monoxide	4%– 3%
	Oxides of nitrogen	Up to 2%
– For 1968 – 1974 automobiles	Inspection/maintenance can reduce	
	Hydrocarbons	8%–25%
	Carbon monoxide	7%–16%
	Oxides of nitrogen	Up to 7%
• For new cars (1975+)	Inspection/maintenance is essential to preserving high reduction levels produced by new emission control systems	
• For vehicles with retrofit devices installed	Inspection/maintenance will insure continuing emission control effectiveness of add-on devices	

*Summary of pilot program of automobile emission tests performed in the Denver area. An idle test mode was used with emission standards set to reject 50% of the vehicles inspected. Deterioration after maintenance will tend to reduce these effectiveness estimates in the range of 30 - 50% over the year. The data presented in Table 3 reflects both the current vehicle population distribution and vehicle miles traveled.

- **Deterioration is a Problem**

Inspection/maintenance rates high with pollution-control experts because: 1) it gets at the root-cause of pollution emission: the deterioration of engine components, 2) it is effective on new and old automobiles, and 3) it goes hand-in-hand with any engine retrofit program.

Friction, dirt, engine deposits, heat and cold take their toll in the normal operation of an automobile. They cause deterioration of spark plugs, points, air filters, valves, rings, carburetors, and a host of other engine components. The driving conditions which affect component wear are especially severe at the relatively high altitude of the Denver region. Figure 1 illustrates the effects of deterioration of engine components controlling air-fuel ratio.

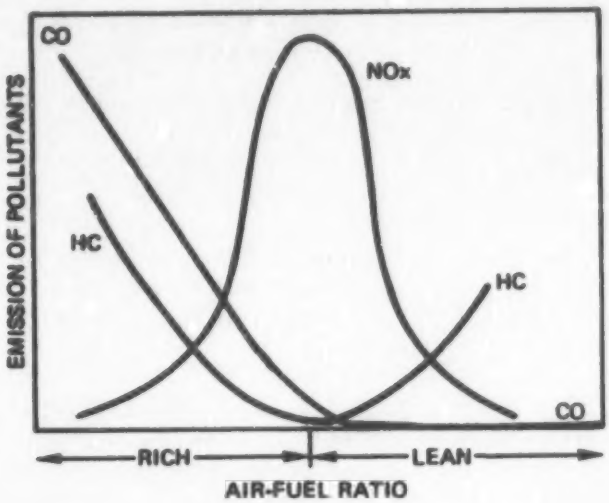

FIGURE 1. AIR FUEL RATIO IS CRITICAL. Changes in air-fuel ratio can increase the emissions produced by the internal combustion engine. Inspection/maintenance can detect these changes and allow proper settings to be maintained.

- **Inspection/Maintenance is the Answer to Deterioration and its Effects on Vehicle Pollutants**

A timely inspection/maintenance program is needed to detect and repair or replace defective parts which are known to be a cause of air pollution. This can be accomplished with a simple and fast exhaust emission test (inspection) followed by any necessary servicing, repair or replacement (maintenance).

THE INSPECTION REQUIREMENTS

Studies of several city and state programs for the reduction of automobile pollutants show that vehicle inspections should include:

- Visual inspection of smog control devices to check for tampering, disconnections, etc.
- Visual check of tailpipe emissions for excessive smoke.
- Instrumented tests of exhaust emissions to measure hydrocarbons, carbon monoxide, and oxides of nitrogen.

There is a continuing debate as to the best method of operating a vehicle during the instrumented tests. Many test cycles have been devised in an attempt to duplicate the normal driving patterns of the average automobile operator; some test cycles take hours to complete. For testing large numbers of vehicles, however, two methods have emerged as being both effective in detecting excessive exhaust emissions and short enough to be reasonable in terms of time and cost. They are the idle operating mode and the loaded operating mode procedures.

Idle Operating Mode

Tailpipe sensors detect exhaust emissions from the automobile under test as its engine is run at normal idle rpm. The transmission is placed in neutral, removing all load from the engine during the test and sufficient time is allowed for the readings of the test meters to stabilize (normally 30 seconds to 1 minute).

There are several distinct advantages and disadvantages to the idle operating mode:

The advantages are:

- Tests are simple to perform and require minimum operator training.
- This method has proved reliable for diagnosing many engine maladjustments and malfunctions that increase exhaust emissions.
- Engine adjustments can be made easily during the test.
- The procedure may be later modified to a two-stage test with the engine operated both at normal idle and at 2500 rpm.

The disadvantages are:

- Engine malfunctions that occur under loaded conditions may not be detected.
- Preliminary data indicates that idle mode is not as effective as loaded mode tests in detecting malfunctions of catalytic converters and other advanced emission control systems.

Loaded Operating Mode

Using tailpipe sensors and instrumentation similar to that used in an idle test mode, vehicle exhaust emissions are monitored with the vehicle's engine operating under load. The drive wheels of the vehicle are supported by the rollers of a dynamometer, allowing the car to be run in gear under load while remaining stationary in the test stand. Built-in power absorbing devices load the drive wheels to simulate normal driving patterns during the test. A transmission-in-neutral unloaded test is normally performed in addition to the loaded phase to complete the test cycle.

There are advantages and disadvantages to the loaded operating mode:

The advantages are:

- With the application of a load to the vehicle drive wheels, the engine is operated under conditions that are similar to street performance.
- This mode includes an idle test. It can simplify the maintenance function by supplying additional information about engine performance under load.
- It requires no connections to the vehicle under test.
- Loaded tests may be required if the state is to monitor the federally instituted warranty provisions for new car emission control systems.

The disadvantages are:

- Additional test equipment is needed, including a dynamometer to load the vehicle drive wheels.
- Vehicle restraints are needed for operator safety during "in-gear" operation.

ESTABLISHING INSPECTION STANDARDS

The selection of emission inspection standards for an inspection/maintenance program requires a consideration of two factors: 1) the amount of pollution reduction, and 2) the costs of implementing the program.

The idea is to find a set of emission standards (rejection levels) for each vehicle class such that the overall emission reduction per dollar is a maximum. Figure 2 illustrates the general relationship between reduction effectiveness and rejection levels for HC, CO and NOX emissions.

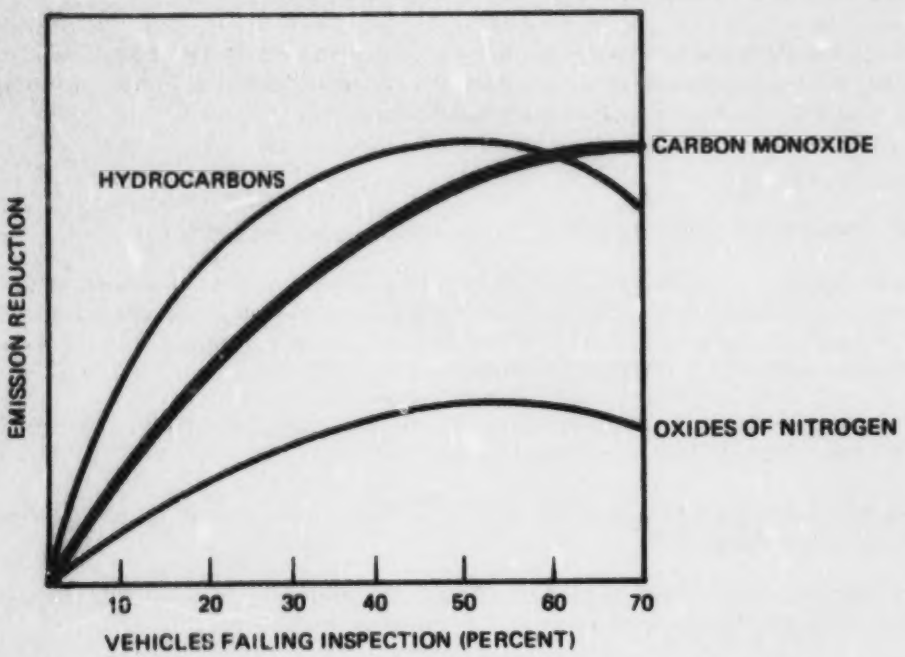

FIGURE 2. PROGRAM EFFECTIVENESS

If the allowable emission standards are set too high, most of the vehicles will pass inspection thereby resulting in relatively low emission reductions.

If the allowable standards are too restrictive (rejecting a large percentage of the population) the resulting emission reductions and costs will be substantially higher. For severe rejection levels, vehicle emission reductions may actually be somewhat lower than for more reasonable standards. (This case is also shown in Figure 2).

Obviously, an acceptable compromise must be made between pollution reduction and costs.

In a test of Colorado vehicles, the best pollution reduction per dollar spent resulted when the emission standards were set so that between 40% and 60% of the vehicles tested required some adjustments or repair.

THE INSPECTION CYCLE

In determining how often inspections should be made, it is important to consider the deterioration rates for engine components and emission control devices. Too much time between inspections will reduce the effectiveness of the program, and too short a time will increase costs without appreciably improving air quality.

Most of the regions that have adopted inspection/maintenance programs require an *annual* inspection cycle. A recent study has been made of the Denver region to determine the deterioration rates of engine components. The data from this study will shed more light on whether or not an annual inspection is adequate for this region.

THE CASE FOR STATE INSPECTION VERSUS PRIVATE INSPECTION

One of the major decisions to be made regarding an inspection/maintenance program is whether to have public-operated or private-operated inspection stations. Following are some of the good and bad points for each of these two options.

State Inspection Lanes

There are a number of distinct advantages to having state lanes, including:

- Fewer inspection lanes are needed to handle the predicted number of vehicles in the Denver Air Quality Control Region. With a state-operated station, pollution inspection would be the only function, and vehicle processing rates would be on the order of ten times higher than for a private-operated station.
- State facilities make it practical to have multiple lane inspection stations. Test equipment can be readily shared by pairs of lanes.
- Data handling and processing can be simplified. Computer terminals at each station is a reasonable possibility.
- It is more effective to have state-operated stations monitor the repair and maintenance which is handled by the private sector.
- Costs to the vehicle owner are less for a state operated program due to lower labor costs and higher vehicle throughput rates.
- Higher emission reductions can be expected as a result of fewer, tightly controlled, specialized test facilities.

The disadvantages are:

- Vehicles owners failing an inspection must travel to a second location for maintenance and then back for a post-maintenance test.
- A long lead time might be required to develop multiple-lane facilities for state inspections because of construction capacity limitations.

Private Inspection Lanes

The advantages of having the private sector perform vehicle inspection are:

- Safety inspection lanes already exist in the Denver Region. The program can be initiated in a timely manner.
- Inspection and maintenance can be performed at one station for greater convenience to the vehicle owner.
- Minor adjustments can be made by an inspector/mechanic at the time of inspection.
- Large number of stations compared to state run program means greater convenience for the public.
- Many stations could perform exhaust emission inspection, safety inspection and maintenance at the same time.

The disadvantages are:

- Private-operated stations will use highly trained and paid personnel to perform tests that require a lower skill level.
- A large number of private-operated lanes are necessary, yet the private sector will devote only a part of the work day for this function, resulting in a low annual processing rate per lane.

Studies of other regions show that all of the inspection/maintenance programs currently underway use public-operated inspection stations with maintenance being performed by the private sector.

THE COSTS OF THE PROGRAM

Table 4 shows comparative costs for the various options for an inspection/maintenance program in the Denver Air Quality Control Region. These figures are based on the following assumptions:

- The program start date is June 1976.
- Exhaust emission standards are set so that approximately 50% of the vehicles will fail inspection.
- Inflationary factors are considered in the cost projections.
- The inspection fee will make the program self-supporting over a five-year period.
- Annual inspection is required for all light-duty vehicles as registered in the region.
- Deterioration after maintenance is not reflected in estimated emission reduction percentages.

TABLE 4

COMPARATIVE COST DATA

	NUMBER OF STATIONS	INITIAL INVESTMENT	FIRST YEAR OPERATIONAL COST	AVERAGE ANNUAL COST 5-YEAR PROGRAM	% REDUCTION IN VEHICLE POLLUTANTS*			SELF SUPPORTING INSPECTION FEE PER VEHICLE
					HYDRO-CARBONS	CARBON MONOXIDE	NITROGEN OXIDES	
STATE LANES								
IDLE MODE	41	3.2 MILLION	2.6 MILLION	4.0 MILLION	10 - 15	5 - 12	1 - 2	$4.00
LOADED MODE	44	4.0 MILLION	3.1 MILLION	4.6 MILLION	15 - 20	10 - 17	1 - 2	$5.00
PRIVATE LANES								
IDLE MODE	600	2.2 MILLION PRIVATE 502,000 STATE	3.4 MILLION PRIVATE 1.1 MILLION STATE	4.3 MILLION PRIVATE 1.3 MILLION STATE	10 - 15	5 - 12	1 - 2	$4.35 PRIVATE $1.35 STATE $5.70
LOADED MODE	600	5.6 MILLION PRIVATE 690,000 STATE	4.6 MILLION PRIVATE 1.1 MILLION STATE	6.5 MILLION PRIVATE 1.3 MILLION STATE	15 - 20	5 - 12	1 - 2	$6.65 PRIVATE $1.35 STATE $8.00

*These reduction estimates do not include the effects of engine deterioration and owner tampering between inspections. Current evidence indicates that deterioration may reduce these reduction estimates by 30-50% on an annual basis.

PUBLIC OPINION SURVEYS

Public acceptance of an inspection/maintenance program is difficult to predict. Two surveys were taken in the 1971–72 period and the results look encouraging. Most residents seemed convinced of the seriousness of the air pollution problem and the majority agreed that automobile emissions are a prime pollution source. These survey results may not reflect a current public resistance to any program that involves higher taxes or user fees, and they do not account for present inflationary trends.

Question	Percentage of "Yes" Answers
Is automobile pollution a major contributor to air pollution?	
Survey 1	72%
Survey 2	69%

Who should operate emission inspection stations?

	The Government	The Private Sector
Survey 1	42%	49%
Survey 2	44%	52%

What fee should be charged?

Survey 1: 54% want a fee of less than $3.00
Survey 2: The mean of all responses: $4.50

The following questions were asked only in Survey 1:

How often should vehicles be inspected?

Semi-Annual: 59% Annual: 27%

How do you feel about the current safety inspection program?

Approval: 94%

SERVICE INDUSTRY SURVEY

A poll was taken of approximately 20% of the station operators currently enrolled in the Colorado safety inspection program to get their reaction to an inspection/maintenance program. Following are some pertinent results of this poll:

Inspection Fees

Fee for Idle Mode Tests	Percentage of Firms Indicating Interest
Less than $4.00	7%
$5.00	54%
$8.00	79%
$10.00 or more	95%

Test Equipment

Firms now owning equipment for idle mode tests: 32%

Inspection Frequency	Industry Opinion
Six-Months Inspection	51%
Annual Inspection	29%

SOCIO-ECONOMIC FACTORS

In addition to the costs associated with vehicle inspection, there are both direct and indirect costs which must be borne by the vehicle owner. Some represent true out-of-pocket expenses while others are measured in terms of inconvenience and time. In addition, such factors as consumer protection, enforcement and indirect benefits also must be considered in formulating the overall program.

Repair Costs

- Maintenance charges to meet the emission standards are expected to be in range of $10 – $40 but could conceivably exceed $100 for major repairs. Maximum repair service charge should be established to limit the financial impact on the motoring public.
- Owners of vehicles requiring maintenance must be protected from irregular repair practices. Unnecessary repairs or ineffective repairs require consumer protection measures by the State.

Inconvenience

- Travel time to the inspection station, time spent at the station and subsequent repair time represent an inconvenience and potential hardship factor for vehicle owner. State inspection lanes are estimated to be three times more inconvenient in terms of time spent by owner to comply with inspection/maintenance requirements, compared to a one-stop private lane. This inconvenience could be minimized with multiple lane facilities (see Figures 4 and 5).
- Combination safety/emission inspection lanes in the Denver Air Quality Control Region would provide maximum convenience to the vehicle owner, allowing both inspections and any maintenance required to be completed in a single trip.

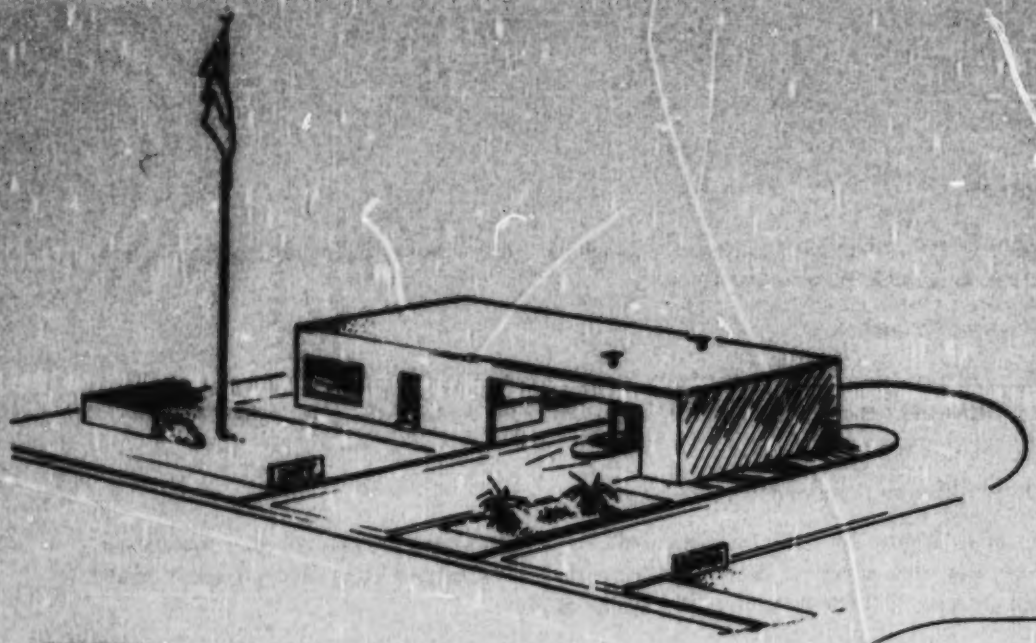

FIGURE 4.
INSPECTION STATION. Artist's Conception of Multi-Lane Exhaust Emission Inspection Facility.

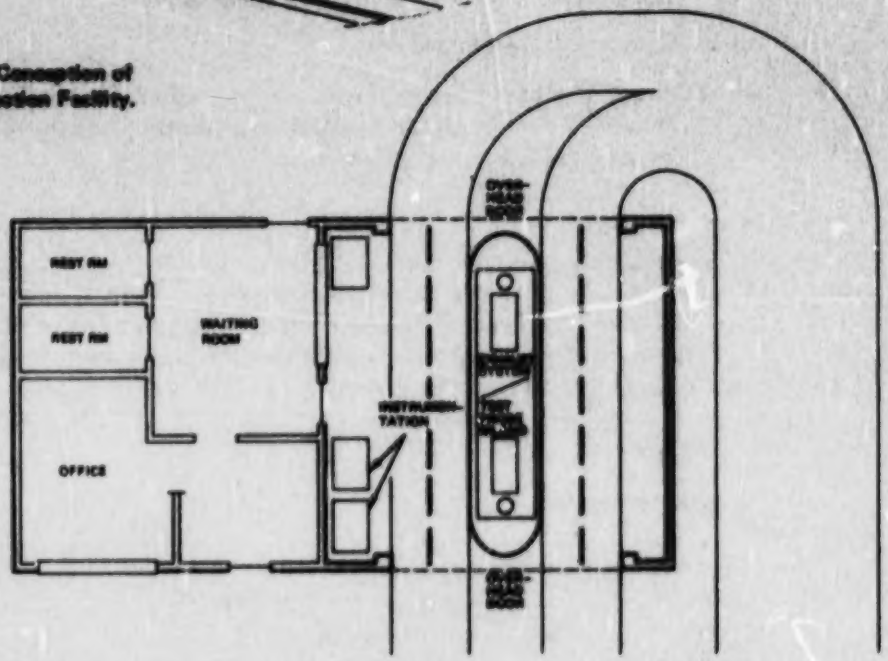

FIGURE 5.
Plan View Two-Lane Inspection Facility

Consumer Protection

- The State of New York, in a report issued by its Department of Motor Vehicles, recommends that vehicle exhaust emissions not be included in their presently operating privately run safety inspection program. Lack of uniformity in inspection practices, difficulty in data gathering, and actual station malpractices and consumer complaints are some of the reasons offered to support that decision.
- No information is available to indicate the degree of repair practice abuse evident in New York exists in the Colorado safety inspection programs, but any new programs must have adequate safeguards to protect the consumers.
- State run inspection lanes provide an automatic check of private sector repair practices as serviced vehicles are retested.

Enforcement

The success of an inspection/maintenance program requires the establishment of companion programs to ensure continuing effectiveness.

- Emissions Surveillance

  Highway monitoring for excessive visible exhaust emissions or instrumented spot checks of vehicles are necessary to control tampering with emission control devices between scheduled inspections.

- Repair Industry Assessment

  The effectiveness of repair industry techniques in reducing emissions is automatically monitored with a state operated inspected lane. If a private inspection system is opted, another method of monitoring must be established.

- Training and Certification

  Maximum effectiveness of the program can be achieved by providing a program to train and certify all inspectors and maintenance personnel in the special methods of exhaust emission inspection and maintenance.

- Exemptions

  By the anticipated program start date, pre-1968 model year cars will represent a small fraction of the Denver vehicle population. Their contribution to the exhaust emission problem is expected to be minor and will decrease as the older vehicles are scrapped. Also, test results indicate relatively small reductions in exhaust emissions by applying inspection/maintenance procedures to this class of vehicles. Therefore, consideration should be given to exempting pre-1968 cars from the mandatory elements of an inspection/maintenance program.

INDIRECT BENEFITS

In addition to the reductions in exhaust emissions resulting from an inspection/maintenance program, several indirect benefits can be expected.

- Improved Operating Performance

  Vehicles undergoing maintenance to meet emission requirements will probably perform noticeably better in terms of engine smoothness and acceleration.

- Improved Fuel Economy

  Many of the vehicle malfunctions that increase exhaust emissions also tend to waste fuel. Correcting emissions problems will increase miles-per-gallon performance.

- Public Participation in Fight Against Air Pollution

  The motoring public will share in the fight against air pollution through participation in an inspection/maintenance program.